Separation of Time Scales at high latitudes in rotating and stratified Flows

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Abstract

Earth's high latitudes stand to be among the first regions affected by climate change issues due to changes induced by melting ice in the Arctic and Antarctic. The dynamics in the high latitudes is affected by the higher rotation rate as measured by the Rossby number. The smaller the Rossby number, the more important the rotation is to the dynamics. This kind of dynamics has given way to Taylor caps, which are Taylor columns in the presence of stratification. These were examined theoretically in Hogg (1973) and experimentally by Hide et al. (1966) and Davies (1972) and in numerical simulations of the hydrostatic primitive equations by Chapman and Haidvogel (1991). They have also been hypothesized to exist in places like Porcupine bank Mohn et al. (2002) through in situ observations.

Motivated by the idea of developing new, nonhydrostatic, regional ocean models we derived new results, based on the method of multiple scales presented in Embid and Majda [1, 2] that address the scale separation between slow- and fast-time scale dynamics in the limit of fast rotation while retaining order one affects due to stratification. We derive new equations and their conservation laws for the slow dynamics and show some high resolution numerical results to support the theory. To leading order the potential enstrophy is slow, while the total energy is composed of both fast and slow dynamics.

Of fundamental importance to regional climate modeling this work shows that the polar regions are *not* hydrostatic, but also simpler than the full 3-D Boussinesq equations. Since the method is not limited to the Fourier Analysis, we present the operator that projects the full 3-D solution onto the null space of the fast operator which could impact the development of multiscale numerical methods and preconditioners.

References

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[2] A. J. Majda and P. Embid. Averaging over fast gravity waves for geophysical flows with unbalanced initial data. *Theoretical and Computational Fluid Dynamics*, 11(3/4):155 – 69, JUN 1998.